Differentiating Affects of Effective Fiber Sources on Performance of Lactating Dairy Cows

Renee Starkey
Starkey.78@osu.edu
Animal Sciences
June 2009

Faculty Advisor:

Dr. Maurice Eastridge
Animal Sciences
2029 Fyffe Court
Columbus, OH 43210
Eastridge.1@osu.edu

Abstract

The aim for this research was to determine if corn stover and straw can be efficiently added to lactating dairy cow diets as physically effective fiber sources. A 5x5 Latin square design was used with 5 multiparous rumen cannulated Holstein cows. The treatments were: 1) CS; corn silage as sole forage source (44.1% forage), 2) ALF; corn silage and 11.5% alfalfa hay (45.5% forage), 3) STW-5; corn silage and 5% wheat straw (39% forage), 4) STW-10; corn silage and 10% straw (46.2% forage), and 5) STV; corn silage and 5.5% corn stover (39.5% forage). The dry matter intake (DMI) was lowest for STW-10 ($P < 0.05$). The body weight (734 kg) and BCS (3.18) were similar among treatments. Milk (35.6 kg/d), milk fat (3.56%), milk protein (2.87%), and MUN (17.4 mg/dl) also were similar among treatments. The different forage sources resulted in similar total tract digestibilities of dry matter (75.7%), organic matter (76.9%) and NDF (63.5%). Rumen pH (6.12), acetate:propionate (3.10), and ruminal concentrations of total VFA, acetate, propionate, butyrate, and valerate were similar among treatments. Concentrations of isovalerate ($P < 0.05$) and isobutyrate ($P < 0.10$) were highest for STW-10 compared to the other diets, and isovalerate was also lower ($P < 0.10$) for ALF than for STW-5 and STV. Feeding the higher level of straw may have caused more rumen fill and thus reduced DMI, which would likely lower milk yield in a longer term study. Feeding similar forage NDF concentrations with corn silage based diets using corn stover, alfalfa hay, and wheat straw can result in similar animal performance and ruminal fermentation with adequate formulation of dietary non-fiber carbohydrates and total NDF.

Introduction

Today's dairy farms are feeding cows in ways to maximize genetic potential in milk yield and reproduction. This has led many farms to feed total mixed rations (TMR), in which amounts of each feed ingredient are added to ensure that each bite contains the proper balance of nutrients. The majority of diets fed to high producing cows contain a large amount of grain, which is highly digestible in the rumen. If a large quantity of starch, from grain, is converted into volatile fatty acids too quickly, the rumen pH may rapidly drop. A prolonged drop in pH of the rumen can lead to the metabolic disorder, ruminal acidosis. Acidosis can result in a decrease in milk fat, dry matter intake (DMI), and fiber digestion, as well as an increase incidence of lameness (Yang and Beauchemin, 2006).

To help prevent the incidence of acidosis, physically effective fiber is added to TMR diets. Physically effective fiber describes the characteristics of fiber sources, particularly the particle size, that affects chewing activity. It has been shown that increasing physically effective fiber in a ruminant diet increases chewing activity and ruminating time of dairy cows (Beauchemin and Yang, 2005). As a ruminant animal chews, the secretion of saliva will increase, and since the ruminant's saliva contains sodium bicarbonate, the acidic conditions that take place from starch digestion will be neutralized. Therefore, dairy cow diets that contain high amounts of starch must contain sufficient physically effective fiber to prevent subacute ruminal acidosis (Zebeli et al., 2006).

Recent studies have compared different effects of forage length and type to compare the physical effectiveness of fiber. Zebeli et al. (2006) found that increasing physically effective fiber does not increase rumen pH indefinitely, that there is actually a quadratic relationship, and a plateau will be reached. Along with forages, cottonseed is commonly used as physically effective fiber because it is about 0.84 as effective as alfalfa silage (Harvatine et al., 2002). Eastridge et al. (2009) reported that alfalfa hay, grass hay, straw, and whole linted cottonseed can be added on an equivalent physically effective fiber basis to corn-silage based diets. Since these forages have a commonality in their ability to provide physical effective fiber farmers, have a choice of which to add to TMR-based diets.

Problem Identification and Justification

On dairy farms across the United States, straw is being added in low concentrations to diets because it provides adequate fiber and promotes the formation of a healthy rumen mat (Eastridge, 2004). However, there is a low availability of wheat straw due to a limit in the number of wheat acres and the demand for the use of straw as bedding. Additionally, straw is only available where there is an abundant production of cereal grain. Therefore, alternative sources of effective fiber are desirable.

In Ohio, at least four times as many acres of corn are grown than acres of wheat. Corn stover is the part of the corn plant that is left over after grain harvesting. Because so many acres of corn are grown in Ohio, there is no limit to the amount of corn stover available as is the case with wheat straw. Additionally, the composition of corn stover and wheat straw is somewhat similar, and the prices are similar on a dry matter basis. Through harvesting techniques, corn stover would be able to be harvested and fed as a feed ingredient to dairy cattle.

While the previous research done with physically effective fiber has considered typical feed ingredients, there has been little consideration to corn stover as a source of effective fiber for lactating dairy cattle. This research investigated the addition of corn stover to a diet for lactating dairy cattle by showing how performance was affected. One of the goals was to provide additional dietary options to farmers when there is a shortage of common feed ingredients or their prices are very high.

Hypothesis and/or Objectives

The aim for this research was to determine if corn stover can be efficiently added to lactating dairy cow diets as a physically effective fiber source. There was also a determination as to if a higher or lower concentration of wheat straw will be more effective in the diet. The ultimate goal of this project was to provide more information about different feed additives to farmers. Therefore, our hypothesis was that corn stover fed at 5% of the diet would be similar in effectiveness as a fiber source compared to alfalfa hay or straw, but that straw would reduce animal performance when fed at 10% of the diet.

Materials and Methods

Animals, Diets, and Experimental Design

A 5x5 Latin square design was used with 5 multiparous rumen cannulated Holstein cows (122 $\pm$ 62 days in milk). The treatments were: 1) CS; corn silage as sole forage source (44.1% forage), 2) ALF; corn silage and 11.5% alfalfa hay (45.5% forage), 3) STW-5; corn silage and 5% wheat straw (39% forage), 4) STW-10; corn silage and 10% straw (46.2% forage), and 5) STV; corn silage and 5.5% corn stover (39.5% forage) (Table 1). The five diets were balanced to be chemically equivalent. Prior to mixing the diets, the cobs were removed from the corn stover to simulate sorting. Additionally, prior to mixing, the alfalfa hay, straw, and stover were ground in a bale shredder. Cows were housed in individual tie stalls and offered a TMR twice daily at 0600 and 1600 h for ad labium intake. The corn silage, hay, straw, and stover were sampled weekly to determine dry matter concentrations at 55°C and to adjust the rations accordingly.

Table 1. Ingredient and chemical composition of experimental diets (% of DM).

Item[2]	Treatment[1] CS	ALF	STW-5	STW-10	STV
Ingredient Composition					
Corn silage	44.1	34.0	34.0	36.1	34.0
Legume hay	---	11.5	---	---	---
Wheat straw	---	---	5.08	10.1	---
Corn stover	---	---	---	---	5.52
Dry shelled corn	15.1	16.4	19.9	18.7	19.0
Blood meal	1.44	1.44	1.26	0.639	1.08
Soybean meal - 48% CP	12.5	10.2	13.4	17.0	13.8
Soybean hulls	23.6	23.8	22.9	14.4	23.3
Feed grade urea	0.419	0.360	0.500	0.359	0.440
Dicalcium phosphate	0.679	0.680	0.620	0.439	0.580
Feed grade limestone	1.08	0.500	1.18	1.30	1.18
Magnesium oxide	0.166	0.166	0.166	0.137	0.148
Potassium sulfate	0.299	0.260	0.300	0.300	0.300
TM Salt[3]	0.500	0.500	0.500	0.500	0.500
Vitamin A premix[4]	0.016	0.016	0.016	0.016	0.016
Vitamin D premix[4]	0.040	0.040	0.040	0.040	0.040
Vitamin E premix[4]	0.060	0.060	0.060	0.060	0.060
Chemical composition					
NDF	38.2	38.7	38.1	39.1	37.9
Ash	6.01	6.26	6.12	6.65	6.10
P	0.35	0.34	0.35	0.32	0.34
K	1.26	1.45	1.32	1.34	1.29
Ca	1.01	0.95	1.00	0.84	0.87
Mg	0.36	0.37	0.33	0.28	0.28
Effective Fiber					
pef[5]	68.7	67.3	66.8	72.0	66.8
peNDF[6]	28.6	29.4	29.2	31.9	28.6

[1]CS = Corn silage as sole forage source (44.1% forage), ALF = corn silage and 11.5% alfalfa hay (45.5% forage), STW-5 = corn silage and 5% wheat straw (39% forage), STW-10 = corn silage and 10% straw (46.2% forage), and STV = corn silage and 5.5% corn stover (39.5% forage).
[2]CP = Crude protein and NDF= neutral detergent fiber.
[3]Contained 0.10% Mg, 38.0% Na, 58.0% Cl, 0.04% S, 5,000 mg/kg of Fe, 7,500 mg/kg of Zn, 2,500 mg/kg of Cu, 6,000 mg/kg of Mn, 100 mg/kg of I, 60 mg/kg of Se, and 50 mg/kg of Co.
[4]Contained 30,000 IU/g of vitamin A; 3,000 IU/g of vitamin D; and 44 IU/g of vitamin E, respectively.
[5] pef = Physical effectiveness factor determined as proportion of particles ≥ 1.18 mm.
[6] peNDF = Proportion of dietary DM as NDF in the particles ≥ 1.18 mm.

Sampling Methods

Each period consisted of 21 d with the last 7 d for sampling. The body condition score (1= thin, 5 = fat) of the animals were taken at the start of period 1, at the switch of each diet, and at the end of period 5. The body weights of the animals were taken every Saturday at 1800 h. The last 3 d of each period were used for collection of milk samples, which were taken in both the am and pm for 4 consecutive milkings for determination of fat, protein, lactose, milk urea nitrogen (MUN), somatic cell count (SCC) and other milk solids. Feed offered and feed refused were sampled daily during d 14 through 18 and were composited for the determination of dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), and particle size. Digestibility of feed components were determined using Cr_2O_3; this was dosed in the rumen twice daily from d 8 through 18 after each feeding at 60 g per dose in pellet form (88.992% soybean hulls and 9.258% chromic oxide). Fecal samples were taken every 12 h during the 4-d collection period, with the starting time being altered by 3 h each day. The fecal samples were dried at 55°C and composited for analysis.

On d 15 and 18 of each period, ruminal mat consistency was measured (Qui et al., 2003). A weight of 0.454 kg was put at the bottom of the rumen at each feeding, with one end of the string left out of the rumen. This string was tied to an object to prevent the string from being pulled back into the rumen. At 3 h post feeding, the free end of the string was pulled through two pulleys and mounted on both ends of a yard stick. A weight of 2.27 kg was hooked onto the end of the string. A marker was placed on the string in order to observe the movement of the weight inside of the rumen. Distance traveled was measured at multiple time intervals until 15 minutes had passed.

Ruminal samples were taken on d 16 and 17 to determine pH and volatile fatty acids (VFA) concentrations. These samples were taken 4 hours after the am feeding. Samples were taken from 9 different parts of the rumen and compostited. A sample of this composite was then squeezed through cheese cloth in order to separate the rumen fluid. The pH of the ruminal fluid was measured immediately. Then 50 mL of the ruminal fluid was added to 3 mL of 6 N HCL to stop fermentation. These samples were frozen until later analyses for VFA.

Laboratory and Statistical Methods

Samples of feed offered, orts, and fecal contents were ground to pass through a 1-mm screen (Wiley Mill, Arthur H. Thomas, Philadelphia, PA). Samples of feed offered, orts, and fecal contents were analyzed for DM, OM, and N (AOAC, 1990). The NDF concentrations of feed offered, orts and fecal contents were analyzed using a ANKOM 200 fiber analyzer (Ankom Technology, Macedon, NY) based on procedures of Van Soest et al. (1991) using heat-stable α-amylase and sodium sulfite. Chromic oxide pellets and fecal contents were analyzed for Cr by atomic absorption spectroscopy (Williams et al., 1962). Feed offered was analyzed for mineral concentrations using inductively coupled plasma emission spectrometry by the Ohio State University STAR lab (Wooster, OH).

The particle size distribution of the TMR was determined using the Penn State Particle Separator, using 3 sieves, 19.0, 8.0, and 1.18 mm (Kononoff et al., 2003). Physical effectiveness factor (pef) was calculated as the proportion of particles retained on the 1.18 mm screen (Mertens, 1997). The pef values were multiplied by the respective NDF concentrations of particles to obtain physically effective NDF (peNDF).

The acidified rumen fluid samples were thawed, centrifuged at 15,000 x *g* at 4° C for 15 min, and filtered through Whatman #1 filter paper. The supernatant was analyzed for VFA concentrations by GLC (Harvatine et al., 2002).

Milk samples were analyzed by DHI Cooperative, Inc. (Columbus, OH) for concentrations of fat, protein and lactose using infrared spectroscopy (B2000 Infrared Analyzer, Bentley Instruments, Chaska, MN) and MUN (Skalar SAN Plus segmented flow analyzer, Skalar Inc., Norcross, GA).

Data were analyzed as a Latin square design with cow as a random effect, using PROC MIXED of SAS (SAS Institute, 2004).

Data and Results

Dry Matter Intake, Milk Yield, and Milk Composition

The dry matter intake (DMI) was lowest for STW-10 ($P < 0.05$) (Table 2). The body weight (734 kg) and BCS (3.18) were similar among treatments. Milk (35.6 kg/d), milk fat (3.56%), milk protein (2.87%), and MUN (17.4 mg/dl) also were similar among treatments.

Table 2. Dry matter intake, milk yield milk composition, body condition, and body weights.

	Treatment[1]					
Item[2]	CS	ALF	STW-5	STW-10	STV	SE
DMI, kg/d	28.6[a]	28.9[ac]	30.5[bc]	26.9[a]	28.6[a]	1.1
Body condition score	3.15	3.35	3.00	3.20	3.20	0.23
Body weight, kg	719	737	735	743	736	34
Milk, kg/d	35.9	34.8	36.4	34.0	37.0	3.6
Milk fat, %	3.36	3.58	3.96	3.22	3.67	0.28
Milk protein, %	2.88	2.85	2.87	2.90	2.84	0.11
MUN, mg/dl	17.3	16.2	18.2	17.9	17.3	1.2

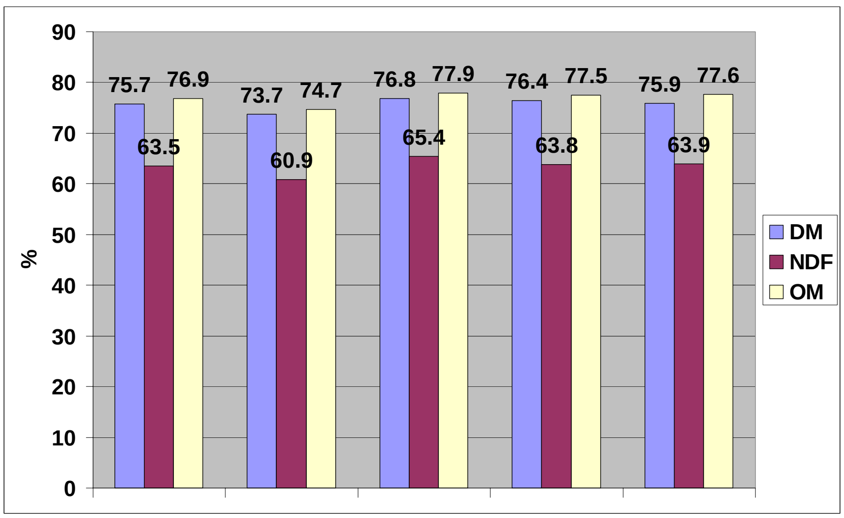
[abc]$P < 0.05$, [de]$P < 0.10$

[1]CS = Corn silage as sole forage source (44.1% forage), ALF = corn silage and 11.5% alfalfa hay (45.5% forage), STW-5 = corn silage and 5% wheat straw (39% forage), STW-10 = corn silage and 10% straw (46.2% forage), and STV = corn silage and 5.5% corn stover (39.5% forage).

[2]DMI = Dry matter intake, MUN = milk urea nitrogen, and SE = standard error.

Digestibility

Figure 1 shows the different digestibilities for DM, NDF, and OM. The different forage sources resulted in similar total tract digestibilities of dry matter (75.7%), organic matter (76.9%) and NDF (63.5%).



	SE
NDF	4.5
OM	2.6
DM	2.8

Figure 1. Digestibility of dry matter (DM), neutral detergent fiber (NDF), and organic matter (OM) (SE = standard error).

Rumen Fermentation

Rumen pH (6.12), acetate:propionate (3.10), and ruminal concentrations of total VFA, acetate, propionate, butyrate, and valerate were similar among treatments (Table 3). Concentrations of isovalerate ($P < 0.05$) and isobutyrate ($P < 0.10$) were highest for STW-10 compared to the other diets, and isovalerate was also lower ($P < 0.10$) for ALF than for STW-5 and STV.

Table 3. Ruminal characteristics.

Item[2]	Treatment[1]					
	CS	ALF	STW-5	STW-10	STV	SE
pH	6.12	6.15	6	6.24	6.08	0.14
Total VFA, mM	157	165	168	160	159	6
Acetate (A), mol/100 moles	63.5	64.9	65.1	64.7	64.5	0.8
Propionate (P), mol/100 moles	21.9	20.9	20.7	20.6	21.1	0.9
A:P	2.94	3.13	3.16	3.16	3.10	0.15
Butyrate, mol/100 moles	11.2	10.8	10.7	10.8	11.0	0.36
Valerate, mol/100 moles	1.47	1.48	1.41	1.46	1.46	0.07
Isovalerate ,mol/100 moles	1.35^{ac}	1.24^{c}	1.45^{ab}	1.62^{b}	1.41^{ac}	0.11
Isobutyrate, mol/100 moles	0.66^{d}	0.62^{d}	0.63^{d}	0.78^{e}	0.64^{d}	0.04
Rumen Matt Consistency						
Distance Traveled first min (cm)	10.42	9.37	8.86	8.93	9.69	2.34
Rate after 1 min (cm/min)	6.44	5.33	5.24	4.93	6.65	1.25

$^{abc}P < 0.05$, $^{de}P < 0.10$

[1]CS = Corn silage as sole forage source (44.1% forage), ALF = corn silage and 11.5% alfalfa hay (45.5% forage), STW-5 = corn silage and 5% wheat straw (39% forage), STW-10 = corn silage and 10% straw (46.2% forage), and STV = corn silage and 5.5% corn stover (39.5% forage).

[2]VFA = Volatile fatty acids.

Conclusions

Feeding the higher level of straw may have caused more rumen fill and thus reduced DMI, which would likely lower milk yield in a longer study. Feeding similar forage NDF concentrations with corn silage based diets using corn stover, alfalfa hay, and wheat straw can result in similar animal performance and ruminal fermentation with adequate formulation of non-fiber carbohydrates and total NDF.

One consideration with feeding corn stover would be mold growth, and careful management should be done on proper harvesting and storage of the crop. When these issues can be addressed, corn stover can be considered as an effective fiber substitute.

Acknowledgements

I am deeply appreciative of Dr. Eastridge for all of his time, patience and guidance. I would like to thank those at the Waterman Dairy farm and Ruminant Nutrition Lab for all their hard work. A special thanks to Paige Gott for her help and support through this project

Literature Cited

AOAC. 1990. Official Methods of Analysis. Vol. I. 15th ed. Association of Official Analytical Chemists, Arlington, VA.

Beauchemin, K.A., and W.Z. Yang. 2005. Effects of physically effective fiber on intake, chewing activity, and ruminal acidosis for dairy cows fed diets based on corn silage. J. Dairy. Sci. 88:2117-2129.

Eastridge, M.L., B.L. Bucci, and C.V.D.M. Ribeiro. 2009. Feeding equivalent concentrations of forage neutral detergent fiber from alfalfa hay, grass hay, wheat straw, and whole cotton seed in corn silage diets to lactating cows. Anim. Feed Sci. Tech. 150:86-94.

Eastridge, M.L. 2004. Straw in rations for dairy cows. Tri-State Dairy Nutrition Conference. The Ohio State University, Columbus. Pgs 107-116.

Harvatine. D.I.. J.E. Winkler, M. Devant-Guille, J.L. Firkins, N.R. St. Pierre, B.S. Oldick, and M.L. Eastridge. 2002. Whole linted cottonseed as a forage substitute: Fiber effectiveness and digestion kinetics. J. Dairy Sci. 85:1988-1999.

Kononoff, P. J., A. J. Heinrichs, and D. R. Buckmaster. 2003. Modification of the Penn State forage and total mixed ration particle separator and the effects of moisture content on its measurements. J. Dairy Sci. 86:1858-1863.

Mertens, D. R. 1997. Creating a system for meeting the fiber requirements of dairy cows. J. Dairy Sci. 80:1463-1481.

Qiu, X., M.L. Eastridge, and Z. Wang. 2003. Effects of corn silage hybrid and dietary concentration of forage NDF on digestibility and performance by dairy cows. J. Dairy Sci. 86:3667-3674.

SAS Institute. 2004. SAS/STAT® 9.1 User's Guide. Version 9.1.3. SAS Inst. Inc., Cary, NC.

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Williams, C.H., D.J. David, and O. Iismaa. 1962. The determination of chromic oxide in faeces samples by atomic absorption spectrophotometry. J. Agric Sci. 59: 381-385.

Yang, W.Z., and K.A. Beauchemin. 2006. Physically effective fiber: Method of determination and effects on chewing, ruminal acidosis, and digestion by dairy cows. J. Dairy Sci. 89:2618-2633.

Zebeli, Q., M.Tafaj, H. Steingass, B. Metzler, and W. Drochner. 2006. Effects of physically effective fiber on digestive processes and milk fat content in early lactating dairy cows fed total mixed rations. J. Dairy Sci. 89:651-668